

water to remove the acetic acid, dried in an air oven at 100° C. for six or eight hours, and extracted for eight hours with ether in the ordinary way, and the extracted fat weighed.

The reliability of these modified methods is shown in Table 5.

In determining the fat in condensed milk there is an added difficulty of the presence of cane sugar. For gravimetric estimation the modified ether extraction method described above is to be recommended. For a rapid centrifugal method, the following modification (by Leach) gives fair results: 15 c.c. of the 40% solution of condensed milk is measured into a Babcock bottle, and enough of a copper sulphate solution is added to precipitate the proteins. The bottle is then centrifuged, and the precipitated proteins carry the fat to the bottom of the bottle. The clear liquid above is then drawn off by means of a pipette having a wisp of cotton wool over the end to prevent any of the precipitate being withdrawn, and the remaining fat and protein is thoroughly mixed with water and again centrifuged. This operation is repeated until the sugar has all been removed. 17.5 c.c. of water is added to the precipitate, then 17.5 c.c. of strong sulphuric acid, and the operation continued as in the ordinary Babcock test. This method eliminates the trouble due to charring of the sugar, but still has the defects connected with the Babcock test when used for evaporated milk.

Milk powders.—In making these the difficulty has been to produce a powder which when mixed with water would produce a fluid similar to milk in appearance, flavour, and physical properties. Many methods have been tried, and numerous patents granted, but, with one or two exceptions, there has been little success. The two most successful processes are by drying on steam-heated rolls, and by spraying the milk into a tower.

In the roller system, the milk is run on to steam-heated metal rolls, generally *in vacuo*. The dried powder is scraped off the rolls, and ground. The resultant powder, while fairly good, is not as soluble as it should be.

The spraying system has been more successful. The milk is first reduced in a vacuum pan to about one-fifth of its volume. It is then atomised into the top of a hot chamber, the moisture being removed while the fine particles of milk are falling to the floor. The dried product accumulates on the floor as a very dry flour, and needs no grinding. The powders produced by these spraying systems are excellent, and find a ready use with bakers, confectioners, etc. For composition see Table 1.

These products are analysed by making a solution the strength of ordinary milk, and analysing this. All the difficulties mentioned for the analysis of evaporated milk are also met with in this product.

Casein.—When the milk supply is too heavy to be handled by the evaporators, it is usual to skim the milk, ship the cream in to the cities, and prepare casein from the skim milk. The present uses of casein are numerous and increasing. They include paints, dressing for textiles, cements and mucilages, plastic masses, sizing for paper, food products (under trade names such as Sanatogen), and many others.

The casein content of ordinary cow's milk averages 3.2%. It is easily precipitated by acids. Technically, it may be made by spontaneous souring of the milk, or more often by the addition of acids, as hydrochloric, sulphuric, or acetic acid; also by precipitation by rennet. Combinations of these methods are also used, the casein being sometimes dissolved in alkali and re-precipitated by another acid. Many patents cover the manufacture of this product, each one of which has its own special claims. The casein is washed and dried on trays, preferably in a vacuum drier. It is then ground.

The trade in America is controlled by two companies, the Union Casein Company and the Casein Company of America, both of which manufacture many products from the raw material.

Those specially interested in casein and its compounds are referred to Robert Scherer's book on "Casein: Its Preparation and Technical Utilisation."

Not infrequently the whey (after the separation of the casein by rennet) is evaporated down, and the lactose obtained. Processes similar to the manufacture of ordinary sugar are used.

London Section.

Meeting held at the Northampton Institute, Clerkenwell, on Monday, January 4th, 1915.

PROF. W. R. HODGKINSON IN THE CHAIR.

PRODUCTION OF NITRATES FROM AIR, WITH SPECIAL REFERENCE TO A NEW ELECTRIC FURNACE.

BY E. KILBURN SCOTT, A.M.INST.C.E., M.I.E.E.

In papers on the "manufacture of nitrates from the atmosphere" read before the British Association, in August, 1911, and before the Royal Society of Arts, in May, 1912, I pointed out that we were entirely dependent upon raw material from overseas from which to make explosives, and in case of war might be in a serious position, and I urged the necessity of starting the production in this country of nitrates from air by electricity.

Messrs. A. McDougall and F. Howles, of Manchester, first made nitric acid from the air in a practical way about a dozen years ago, but Norway has the honour of making the process a commercial success, Professor Birkeland and Dr. S. Eyde being principally responsible.

Although the first installation in Norway of about 160 horse-power was only started about ten years ago, the business has gone ahead with such leaps and bounds that nearly a quarter of a million horse-power is employed for making nitric acid from the air, in that country alone. Some of the furnaces take over 4000 H.P., and one factory absorbs 140,000 H.P., whilst another of 120,000 H.P. is being built.

For several years I have been at work on the problem of evolving a new furnace to work with three-phase alternating current, also a system of working a complete plant with a view to obtaining better yields than are obtained by the present single-phase furnace plants abroad. I propose to give some particulars of the furnace and method of working.

All nitrogen fixation furnaces have electrodes of metal between which alternating current arcs are formed. These arcs are "blown" into flames by a magnetic field or an air blast, and provision is made for the passage of large quantities of air through these flames.

Owing to the great heat of the electric arc, and possibly also to electronisation, some of the air is acted upon and the nitrogen and oxygen combine to form nitric oxide. As this gas dissociates unless it is immediately cooled, it is necessary to provide a cooling zone in close proximity to the flames and arrange for the gas to enter that as quickly as possible.

The principal points to be considered in the design of a furnace are:—

First. To ensure that as much of the air as possible is brought into contact with the arc flames.

Second. To remove quickly and cool the fixed gas.

Third. To dispose the electrodes so as to minimise adjustment and renewals.

Fourth. To provide automatic regulation of current and continuity of working.

Before proceeding to describe my own furnace it will be an advantage to describe briefly those in use abroad.

The Birkeland-Eyde Furnace.

The best-known furnace is that due to Birkeland and Eyde. At the Notodden works in Norway there are 32 of them of 600 to 1000 K.W. each, and at the Saaheim works there are 8 of 3500 K.W. each. The furnace consists

naces are connected in delta as shown in Fig. 2. The full voltage between phases is available at the terminals of each furnace, and at Notodden this is 5500 and at Saaheim 11,000 volts.

A peculiar feature of the arc flames of this furnace is that in moving along the electrodes they do not do so concentrically but somewhat as shown by the circular broken lines indicated diagrammatically in Fig. 1b.

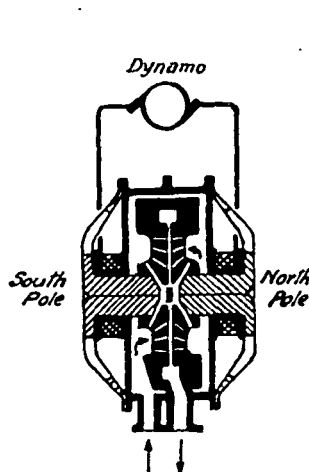


FIG. 1A.

Birkeland-Eyde single-phase furnace with magnetic field for blowing the arc flame.

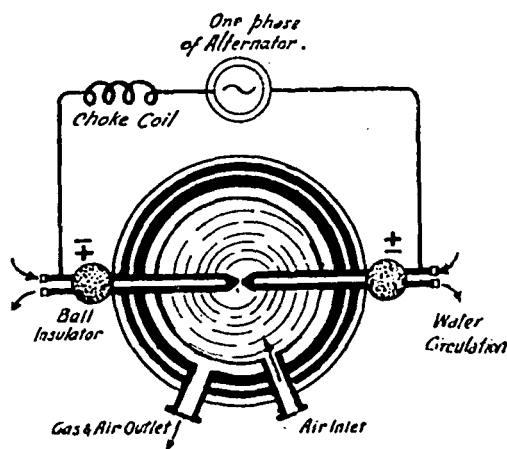


FIG. 1B.

of steel castings built up as shown in Fig. 1A and having between them a cylindrical structure of firebrick, shown in black, with a disc-shaped chamber in the centre. Air enters by a pipe at the base of the furnace and passes into the central chamber by means of a large number of small holes. After flowing radially through the central reaction chamber it collects in a circular channel just inside the periphery of the furnace and passes to the outlet pipe and away. Two U-shaped electrodes project horizontally into the disc chamber from each side, as shown in Fig. 1b. They are made of copper tubes $1\frac{1}{4}$ in. diam. and about $\frac{1}{2}$ in. thick, and the total length of each tube before being bent into shape is about 20 feet. Each electrode is adjustable vertically and sideways. Arcing tips of copper are attached to the rounded ends of each tube, and these tips are spaced about one-third of an inch apart when in the normal position. Cold water circulates through each electrode in insulated pipes, as indicated by the arrows in Fig. 1b.

It is a peculiarity of this furnace that both alternating current and direct current are used. The former is for the arc and the latter for the powerful electric magnet, the north and south poles of which are shown, in Fig. 1A, embedded in the firebrick lining. The direct current supply is indicated at the top of Fig. 1A, and the alternating current single-phase supply at top of Fig. 1B.

The magnetic field is at right angles to the electrodes, and consequently, when alternating currents flow, the magnetic field blows or deflects the arcs outwards into the disc-like chamber. As each electrode is alternately positive and negative, the arc flames are projected rapidly first to one side and then to the other, so that to the eye there appears to be a constant circular sheet of flame. In the 1000 K.W. furnaces the flame is about 6 ft. diameter and in the 3500 K.W. furnaces 8 ft. diameter. The pole faces are about 25 cm. apart, and the magnetic field is about 5000 C.G.S. lines per sq. cm., consequently very large magnetising coils are necessary, and about 10% of the total energy is required to excite them.

It should be especially noted that this furnace works with single-phase alternating current, and therefore on a three-phase circuit the furnaces must be used in sets of three. The design is such that it is not possible to utilise all the three phases in a single furnace. The three fur-

naces are connected in delta as shown in Fig. 2. The full voltage between phases is available at the terminals of each furnace, and at Notodden this is 5500 and at Saaheim 11,000 volts.

At the International Congress of Applied Chemistry in 1912 Dr. Samuel Eyde gave the temperature of the flames as 2500° C. to 3000° C., and the temperature of the escaping gases between 800° and 1000° C. He also stated that the most exposed parts of the electrodes of the furnace require to be changed every third or fourth week and the lining every fourth to sixth month. Each of the furnaces at Saaheim is said to take just under 2000 cub. feet of air per minute.

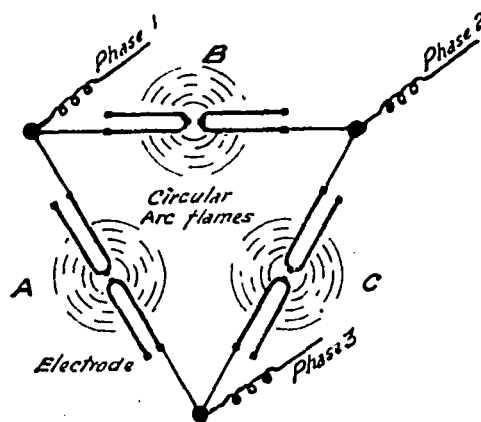


FIG. 2.

Three Birkeland-Eyde furnaces connected in delta.

The Schönherr-Hessberger Furnace.

This furnace is used at the Christiansand works of the Badische Anilin und Soda Fabrik, where there are 12 furnaces of 450 K.W. each; at the Saaheim works there are 96 of 1000 K.W. each.

The apparatus consists of four annular steel tubes arranged vertically as shown in Fig. 3. The outer tube is about 3 feet diameter, is made of plates riveted together, and is lined with firebrick. The innermost tube, about 6 in. diameter, forms the reaction chamber, and up the centre a standing arc flame is maintained by means of a

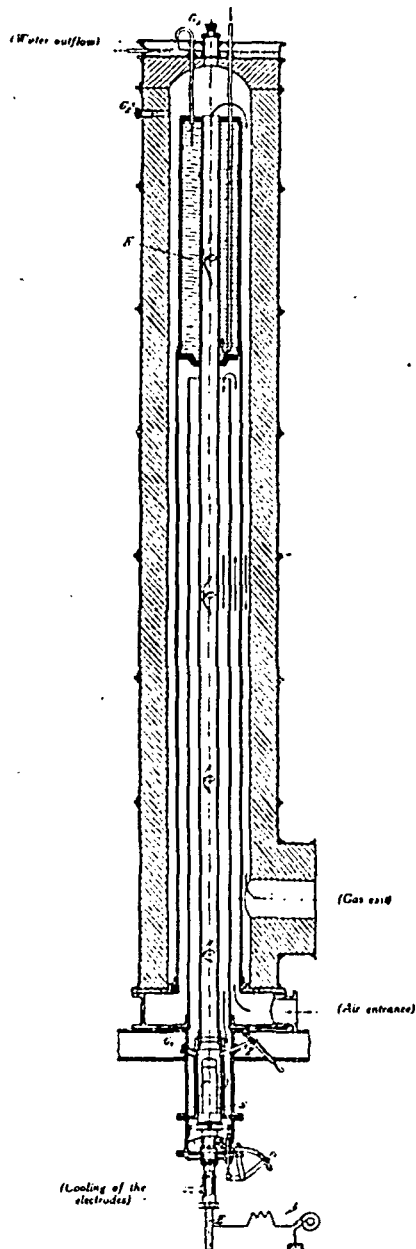


FIG. 3.
Schönherr-Hessberger single-phase furnace, with combined preheater.

whirling current of air. The air inlet and outlet tubes are so arranged that outgoing hot gases preheat the incoming air as indicated by the arrows in Fig. 3. It is therefore a furnace and a preheater combined. By means of a number of tangentially arranged air inlets at the bottom of the reaction tube, the air is given a whirling motion, which helps to keep the arc flame in the centre of the tube. The pressure of the air at the bottom is equal to 50 to 100 cm. of water.

The bottom electrode consists of an iron rod insulated from the furnace. It passes through a water-cooled copper gland, and as it burns away is pushed upwards, fresh rods being screwed on as required to give continuity of working.

The arc is started by means of a lever (marked Z in Fig. 3), which is momentarily placed between the bottom electrode and the reaction tube, the latter being of course at earth potential. The whirling air current then extends the arc upwards to a water-cooled electrode, K, at the top. The top of the arc plays about inside this electrode, and pits the surface.

Some of the air comes in contact with the arc flame and is converted into nitric oxide, and at the top, where the arc strikes from the centre to the side, the fixed gas mixes with the rest of the air that is whirling past. This and the water jacket of the electrode act as the cooling zone. Experience has shown that good yields of gas can be obtained when the air travels parallel to the arc. The furnaces are connected in star as shown in Fig. 4.

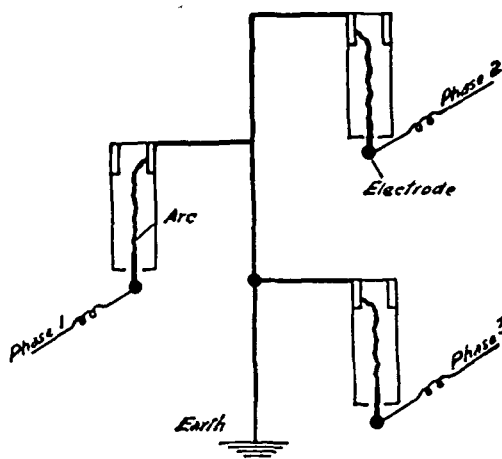


FIG. 4.
Three Schönherr-Hessberger furnaces connected in star.

Although claims for three-phase working are made in the Schönherr patent and three arc flames are shown inside one tube, they could not work that way, as they would collapse together. Also it would be impossible to have three separate whirling air currents in one tube.

As compared with the Birkeland-Eyde furnace, the Schönherr-Hessberger has the advantage of using only one kind of electric current, and there is thus less electrical gear. Other things being equal the energy required for a given output of gas should be less, and in actual practice this appears to be the case.

The 450 K.W. furnaces at Christiansand have standing arcs about 15 feet long and the 1000 K.W. furnaces at Saaheim have arcs about 20 feet long. This makes the furnaces very long and difficult to repair, e.g., those at Saaheim are about 40 feet high.

The relatively great height of the furnace, combined with the difficulty of maintaining so long an arc, presents considerable mechanical and electrical difficulties in building for large powers. That is partly why the furnaces at Saaheim are only for 1000 K.W., whilst the Birkeland-Eyde furnaces are of 3500 K.W.

This question of the limiting size of furnace is important because it would appear that the larger the furnaces the better the yield for a given amount of electrical energy and for a given expenditure in furnace plant. This is always the case when radiation losses form a large part of the total power.

The Pauling Furnace.

The Pauling furnace is used in nitric acid factories at Gelsenkirchen, Innsbruck, and Milan, also at Roche de Ramo, France, and in South Carolina, U.S.A.

The furnace is built on the lines of a horn type arrester—that is to say, it has two electrodes which diverge so as to give a fan-shaped space between them, and has an air blast which fills the fan-shaped space with flame, as shown diagrammatically in Fig. 5.

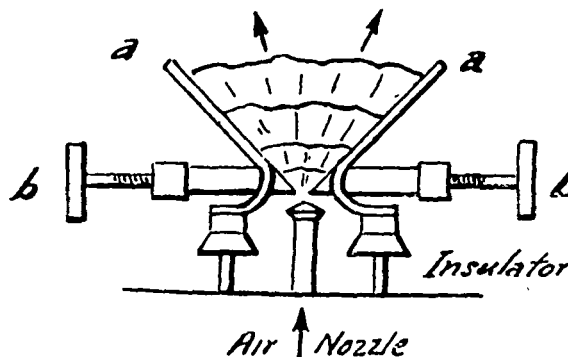


FIG. 5.

Diagram of the Pauling single-phase furnace.

To get the continuous blown arc flame it is necessary first of all to set the electrodes at such a distance apart that the applied voltage will easily jump across, and, second, to blow air between the electrodes so that directly an arc is struck it is immediately forced upwards and goes out, to be followed by others at each half-cycle of the alternating current. There is a separate Pauling furnace to each phase and each has two pairs of electrodes connected in series. There are ducts for the supply of air and a chimney at the top to carry off the gases. Two separate supplies of air are provided; one is preheated and goes to the bottom of each set of electrodes, and the other, which is for cooling purposes, strikes into the top of the arc flames. The velocity of the cooling blast may be less than the other, so as to mushroom out the flames at the top to facilitate cooling.

In order not to dilute the newly-fixed gas the cooling blast consists of some of the air and fixed gas which has passed through the furnace and been cooled down.

The electrodes are of cast steel piping and each is in three pieces, so that the enclosed portion can be reversed when it is burnt or fritted. The electrodes are set several inches apart to allow the air supply to pass through, and from each electrode there projects a starting or kindling blade of thin copper set on edge so as to obstruct the air as little as possible. These kindling blades are approached to within about 3 millimetres of each other, and as they burn away are fed forward. They pass through the bottom horizontal bar of the main electrode. Each main electrode is carried on a triangular frame by insulators, and adjusting screws are provided to set it accurately.

The two pairs of electrodes are in series and the middle point is connected up to a high resistance in such a way as to bring a high voltage to bear on the gap between one pair of electrodes. This establishes the arc, and the tension at that point then sinks so that nearly full pressure is available for the other pair of electrodes. In this way a pressure nearly as high as that available for kindling the first arc is now active in kindling the second one, and in the instant when the latter is formed the circuit is completed through the two arc flames.

Although the Pauling furnaces at present in use are smaller than those employed in Norway, the design is such that there are no physical limitations as to size and height, etc. The structure of the furnace is simple as compared with the furnaces used in Norway, and repairs can be carried out easily. The air passes straight through the furnace without any devious or throttled passages.

Comparison of above furnaces.

Comparing the above it will be seen that the furnaces are of three distinct types, as follows:—

The Birkeland-Eyde is a *Magnetically Blown Arc Furnace*; the Schönherr-Hessberger is a *Long Standing Arc Furnace*; and the Pauling is an *Air Blown Arc Furnace*.

Each furnace is supplied with single-phase alternating current and the first two have single arc flames, whilst the Pauling has two separate arcs in series on a three-phase supply. All the types of furnaces are therefore worked in sets of three.

In the first and the last types the cooling is effected by blowing cool air into the top of the arc flame, whereas in the Schönherr-Hessberger furnace the only air which passes is that previously preheated in the furnace itself.

The Birkeland has the disadvantage that it is necessary to use direct current as well as alternating current. This not only uses up a considerable amount of electric energy but necessitates additional apparatus. Blown arc flames can be obtained just as effectively by an air blast.

From the standpoint of accessibility, the design of the Schönherr-Hessberger is perhaps most at fault, and its great height makes it difficult to construct for large powers. It is the only one with a combined preheater, but there is no advantage in this. For example at Saalheim there are 96 preheaters, whereas two or three separate ones would preheat all the air for the 96 furnaces more effectually and be very much cheaper.

The Birkeland-Eyde furnace has the most complicated refractory lining, and it is in close proximity to the arc flame it is expensive to maintain. The throttled and devious nature of the air path through the furnace requires considerable power to circulate the air, and it should be noted that when comparing various designs, it is necessary to take all the power into account.

When connected on a three-phase supply, three Birkeland-Eyde furnaces require six high tension electrodes, whereas three Schönherr-Hessberger furnaces require only three high tension electrodes, the other three being at earth potential. On the other hand three Pauling furnaces require no less than twelve high tension electrodes.

The electrodes of the Schönherr-Hessberger furnace are simpler and cheaper than those of the Birkeland-Eyde, which being of copper are expensive to renew. The electrodes of the Pauling furnace are complicated by reason of the copper kindling blades which require adjustment and renewal. There is also a possibility of water leaking from the joints.

Experimental apparatus.

Considering the universality of three-phase apparatus it is rather surprising that those interested in nitrogen fixation factories abroad should have kept to single-phase designs. It may be due to patent and royalty considerations and absence of competitive conditions.

In some respects the present position is somewhat similar to that which obtained when three-phase alternators first came to the front. Until then single-phase had always been used, but very soon single-phase designs went out of use. Three-phase supply is now practically universal. When I commenced to develop a new design of nitrogen fixation furnace I decided that the proper thing to do was to choose such a method of producing the arc flames that the furnace could be constructed as a self-contained three-phase unit having only three electrodes.

Until I had actually demonstrated my three-phase furnace at work there were several who anticipated difficulties in starting three arcs, also trouble from unequal burning away of electrodes, unequal balancing, etc. Experience has shown conclusively that none of these difficulties exists. The furnace works much better and steadier than a single-phase furnace, and this has been remarked upon by several who have seen both types at work.

When current has to be taken from a general power supply the importance of having a three-phase furnace cannot be over-estimated.

In such negotiations as I have had for a supply of electric energy, I have generally been asked whether the load would be balanced and what were the chances of continuity of working.

When a company owns its own water power, as in Norway, and has plenty to spare, with no other consumers to consider, then such questions as maintaining a balanced and a constant load on all three phases is not so important.

Fig. 6 shows the lay out of my experimental plant as fitted up at the Northampton Polytechnic Institute, Clerkenwell (by permission of Dr. Mullineux Walmsley).

closed, a stream of high tension sparks immediately jumps across from the wire to the electrodes. The air dielectric being thus broken down, the main three-phase current can then follow. These two electrical circuits do not interfere with each other.

The bottom ends of the main electrodes are set far enough apart to allow the air to pass freely, and they do not require any adjustment because the pilot sparks always make a path for the main current to get across.

The operation of starting up the furnace is very simple. First turn on the air blast, then close the isolating switch

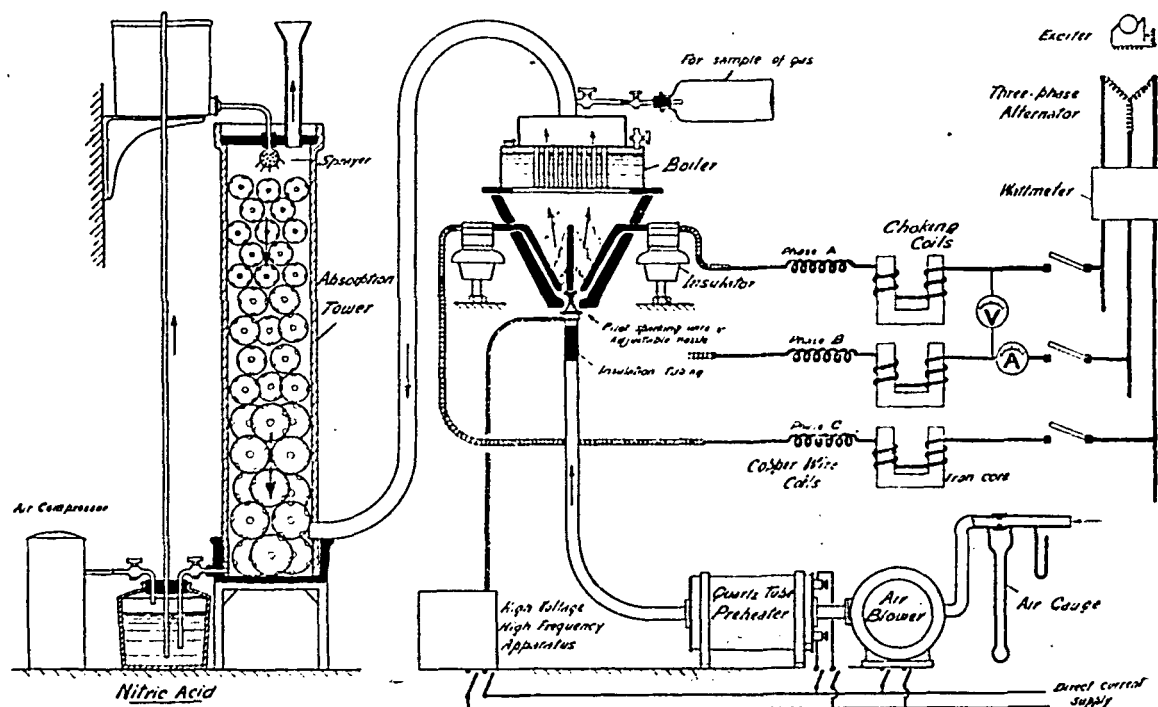


FIG. 6

Experimental Apparatus.

Three-phase current at 2000 volts, 25 periods, supplied from the power house of the Institute passes via a watt meter and three-pole isolating switch to two sets of choking coils. The first has U-shaped laminated cores, and it is possible to regulate the choking effect by connecting more or less coils in series. The second consists of insulated tubes on which a single layer of wire is wound. These latter are to take care of sudden rises of pressure. The proper proportioning of the choking effect is a most important factor, a point which I early appreciated when assisting Mr. Howles in nitrogen fixation experiments about 14 years ago.

The three electrodes of the furnace are attached to double petticoat porcelain insulators spaced 120° apart, two of which are shown in the centre of Fig. 6. The electrodes are of steel, and the inclined sides are bent at about 30° from the vertical line. A standard fireclay crucible serves as the wall of the furnace. The bottom of the crucible is drilled through, and immediately beneath is the air-supply pipe, the nozzle of which consists of an iris diaphragm.

The upper portion of the pipe is made of insulation material and a No. 18 gauge iron wire is attached to the nozzle so as to project vertically upwards with its point midway between the three electrodes and just below them. This wire is for the pilot sparks and it is connected to a high frequency high voltage apparatus somewhat similar to apparatus used in wireless working.

Current from an ordinary lamp pendant supplies the apparatus, and when the tumler switch of this circuit is

so as to make the electrodes alive and finally close the tumler switch of the high frequency set. Directly this is done the sparks jump from the wire to the electrodes and the three-phase arc flames are started. To stop the furnace, the tumler switch is switched off and the arc flames then stop.

Air is supplied by an electrically driven blower, and it is measured by a manometer as indicated at the right-hand bottom corner of Fig. 6. It is only necessary to measure the difference in height of liquid in the U-tube, and then by means of a formula the amount of air is quickly calculated. The method is much more handy and cheaper than a meter; besides, with a wet meter the air may take up moisture.

The three phases working together give a combined flame of more or less inverted cone shape. The air enters this and blows the arc flames up to a point at the top which flickers about like an ordinary flame.

On top of the furnace (in fact the roof) is a boiler with vertical copper tubes for the gases to pass through. The position of the boiler can be adjusted vertically. It is, of course, connected to earth. As the peak of the arc flame is the neutral point of the three-phase supply it does not matter if it strikes on to the bottom of the boiler. As a matter of fact during the experiments I have frequently placed the boiler so low as to cut off a considerable portion of the upper zone of flame. Although the tubes are only soldered into thin tinplate, there was no difficulty in doing this, for the steam raised in the boiler carries off the heat very rapidly.

In the pipe leading from the boiler a cock is provided to allow of the gas being drawn into glass bottles from which the air has been exhausted. This is the usual method of testing.

a cross-section through the boiler. The construction of the electrode should be noted. It consists of a steel tube divided longitudinally into two parts so that the cooling water travels down one side and up the other.

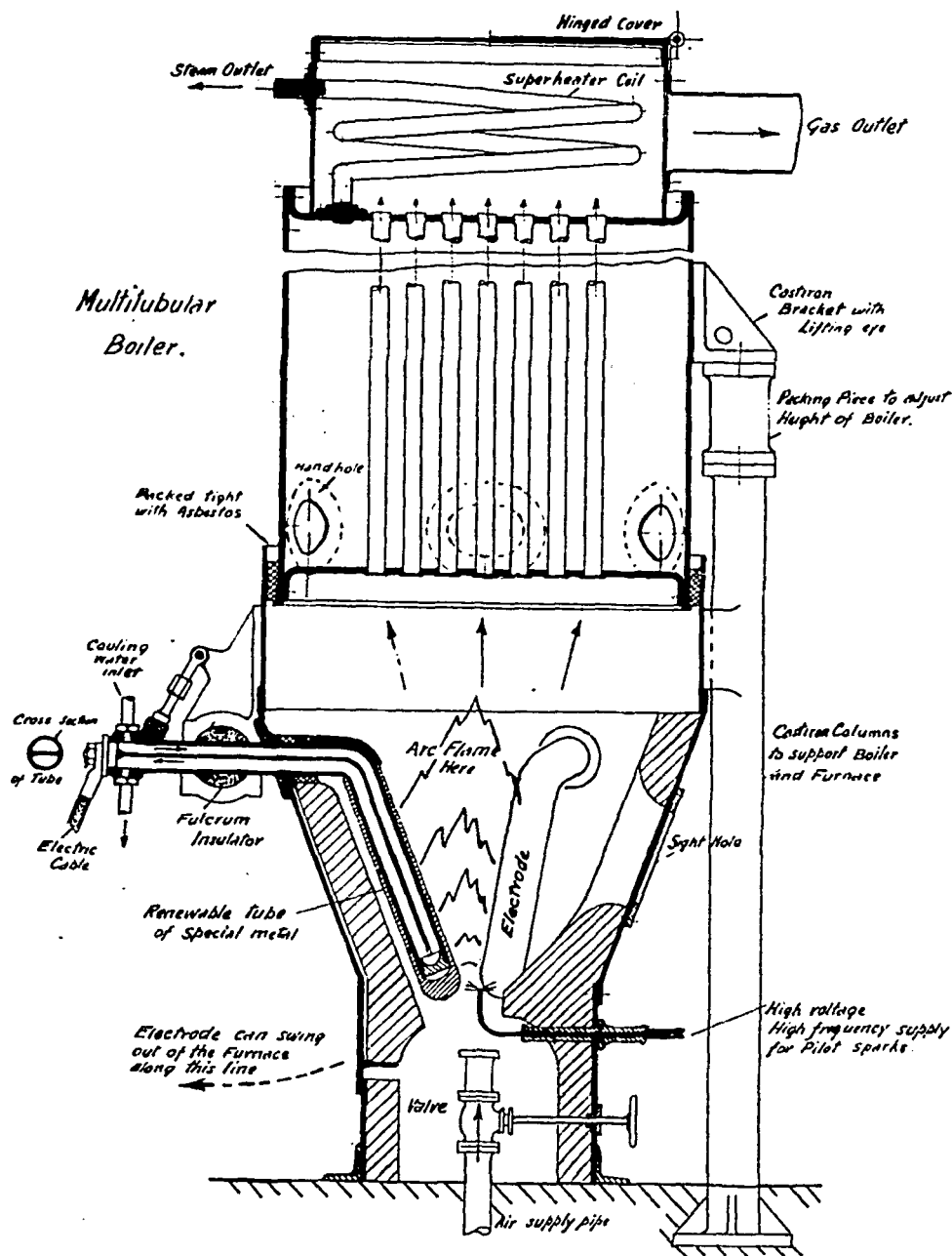


FIG. 7.

Kilburn-Scott three-phase furnace for fixation of nitrogen

For the purpose of absorbing the gases an earthenware pipe filled with Guttman hollow balls is provided. See left of Fig. 6. Water trickling down meets the gas going up, and so forms nitric acid which collects at the bottom. The liquid can be raised by compressed air and so passed through several times.

Kilburn-Scott Three-phase Furnace.

Fig. 7 shows my design of a full-sized commercial furnace and Fig. 8 shows the plan of the three electrodes and also

A renewable tube of cast steel is slipped over the cooling tube from the bottom, and when one side of it is burnt or pitted by the arc flames it can be turned round to present a new surface. The turning can be done in a few minutes. This form of electrode has the advantage of giving minimum insulation where it passes through the furnace wall, for if there were horizontal limbs top and bottom both these would have to be insulated. Also by dispensing with a horizontal bar at the bottom it is much easier to arrange for the pilot sparking conductor and the air

supply. The electrode swings from a large insulator at the outer end of the horizontal limb, so that the electrode can be quickly swung out of the furnace and also swung back again with the certainty of returning to its correct position. The pilot sparking conductor passes through a porcelain insulator fixed in the wall of the furnace below the electrodes, which part of the furnace is of course comparatively cool.

The boiler is carried by three cast iron columns which are at 120 degrees apart and set between the three electrodes. Space for adjustment is provided between the furnace and the boiler, so that the height of the boiler above the electrodes can be varied to suit the size of the arc flames and the velocity of the air. The bulk of the brickwork is remote from the arc flames, so that ordinary plain fire-bricks can be used. As all brickwork and refractory material is porous to a certain extent, the whole is enclosed with thin steel plates which are electrically "earthed" and sectionised.

Three arcs together help to maintain each other because current is always flowing in one or other of the phases. Thus continuity of working is assured and the load is always balanced. When current is purchased from a power station these are most important matters.

By breaking down the air dielectric with high frequency pilot sparks, the arcs start directly the zero points of the alternating current waves are crossed and this improves the efficiency and power factor. There are no kindling knives to burn away and get in the way of the air supply.

The electrodes can be placed at the most suitable distance for the air supply and do not require any adjustment whatever. The control of a large furnace can be effected by a small tumbler switch on the high frequency apparatus.

The boiler forming the roof of the furnace cools the fixed gas very effectively because of the latent heat of steam, and at the same time the steam so raised can be used to generate electric energy, so that the combination can work regeneratively.

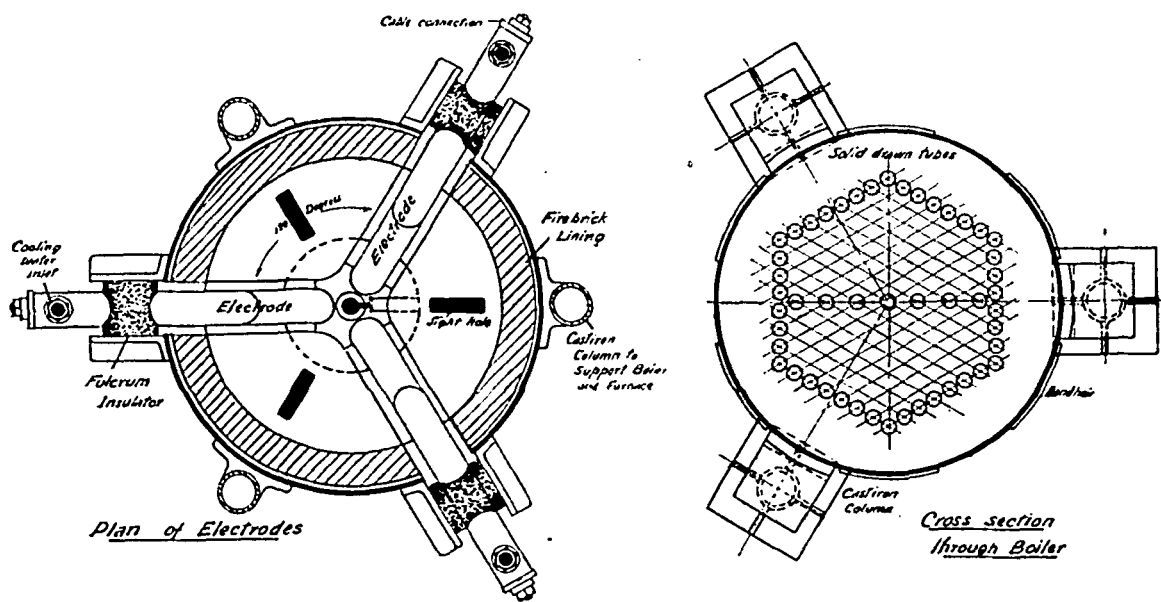


FIG. 8.

Kilburn-Scott three-phase furnace.

The boiler shown has straight tubes, and although it would be better to have a good clean water feed I do not anticipate trouble even if the water should not be very good. Experience with the Bonecourt boiler shows that with very high temperature and good circulation there is little tendency to form scale.

The following may be said to be the special features which distinguish my furnace from those used in Norway and elsewhere.

It is essentially a three-phase furnace using the electric energy exactly as generated, and giving three arc flames within one furnace wall. Also for a given periodicity of supply, thrice as many arcs in a given time as would be the case with single phase.

The three phases give a combined flame of conical shape which is hotter than if the same energy were expended in three separate furnaces because the latter have only a single flat flame and the radiation losses are much greater. The greater bulk of the three phase flame also enables more air to come into contact.

As compared with three single phase furnaces the first cost, the attendance cost, and the maintenance cost are all lower. The space occupied is also much less and there is less brickwork, ironwork, foundations, piping, etc. There are only three electrodes as compared with six for three single phase furnaces and this considerably simplifies the electrical and water connections and the renewing of electrodes, etc.

Method of Working.

The regenerative working is indicated diagrammatically at the extreme left of Fig. 9. The steam turbo-3-phase alternator may be taken to represent a complete power plant, or it may be merely auxiliary to a bulk supply received from some instance away. A pipe connects the electric furnace boiler to the steam turbine.

The turbine may get its steam from the furnaces only and thus be of a low pressure type, or it may also receive a supply from a main high pressure boiler, in which case it would be of the mixed pressure type. In any case this is well-known steam engineering practice, and so long as steam is available from the furnace boiler good use can be made of it.

Some figures for a furnace plant taking say 1000 kilowatts will show the value of such regenerative working.

One k.w. hour equals 3417 British thermal units of heat, so the plant will absorb 3,417,000 B.Th.U. units per heat.

To evaporate one pound of water into steam at 150 lb. per square inch 1100 B.Th.U. units are required, and assuming an efficiency of only 80% the boiler should give

$$\frac{3,417,000 \times 0.8}{1100} = 2500 \text{ lb. of steam per hour.}$$

A turbo alternator using this steam at the rate of say 10.5 lb. of steam per k.w. hour will thus give

$$\frac{2500}{10.5} = 150 \text{ kilowatts.}$$

That is to say the regenerative value of steam raised by the furnace is about 15 per cent.

The saving may be taken as being fully as much as that because in addition to the saving in electric energy there are a number of incidental advantages in connection with such regenerative working not the least of which is the very effective cooling of the fixed gas.

Of course the steam could be regenerated at low pressure, but that is in no way a disadvantage because low pressure steam turbines working on a good vacuum are very efficient pieces of apparatus as witness the many exhaust steam turbines now in use. It merely means that more steam would be generated at the lower pressure.

It will be readily seen that the furnaces used in Norway are not suitable for the application of a boiler directly. Utilisation of steam in a prime mover would necessitate generating plant quite different from the water power plant to which they are accustomed and have plenty of. In this country steam generating plant is almost universal, and conditions are in every way favourable to the utilisation of heat; indeed, the ideal combination would be to build a nitric acid factory alongside an existing steam power-station.

Such steam as is raised in the Norwegian plants is merely that necessary for general purposes in the factory for evaporation, etc., and they obtain all they want from the gases after they have been first cooled down to about 400°C . This in itself shows the great amount of heat energy that is wasted.

Three phase current is supplied to the furnace through choking coils and it will be noted in Fig. 9 that near the furnace I have shown diagrammatically an oxygen making plant and a preheater.

The oxygen may come from some process of which it is by-product or it may be made specially, but in any case the question of its purity is quite unimportant. It should be noted that there are two oxygen supply pipes, one joins with the air supply pipe to the preheater and furnace and the other goes to the oxidation tower.

The concentration of nitric oxide has the highest value at each temperature when the product of oxygen and nitrogen is a maximum. It can be shown that it is directly proportional to the square root of the product thus:—Oxygen and nitrogen as in air $= 0.21 \times 0.79 = 0.16$. Equal parts oxygen and nitrogen $0.5 \times 0.5 = 0.25$.

Then as

$$\sqrt{\frac{25}{16}} = \frac{5}{4}$$

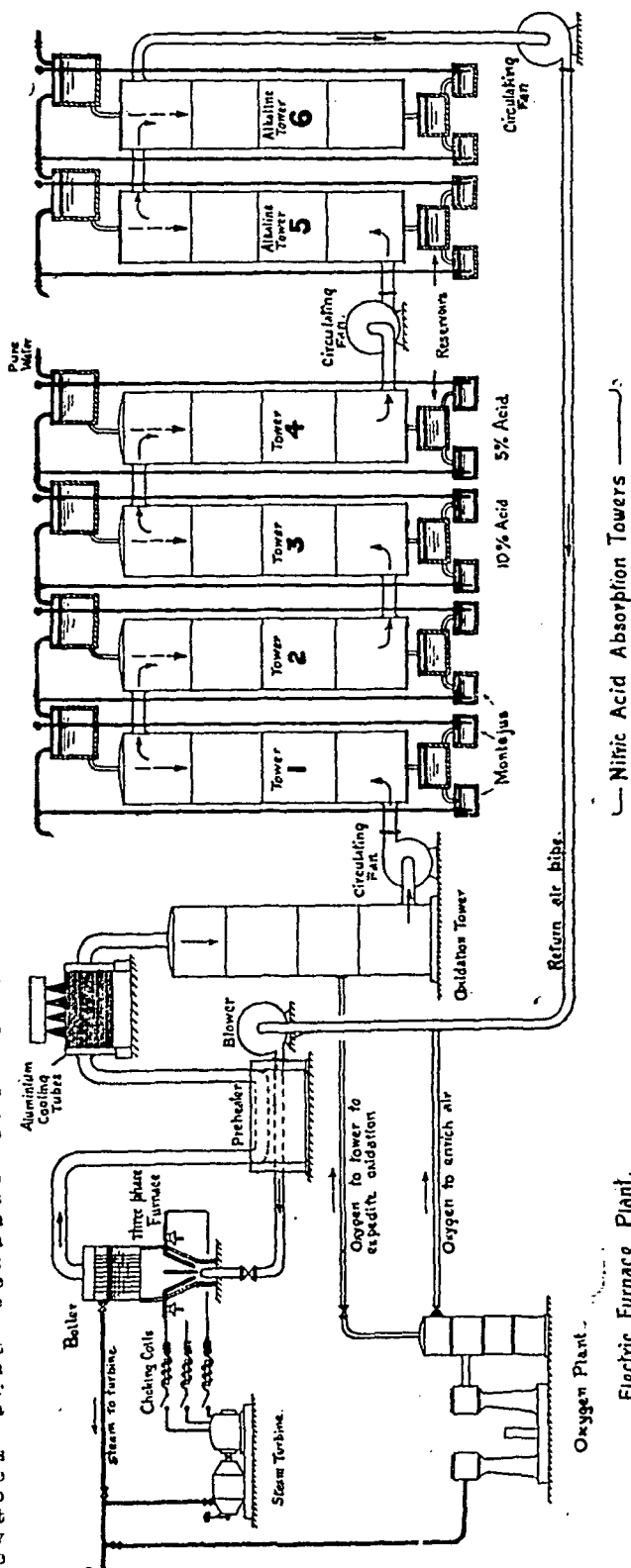
The increased yield is therefore as 4 is to 5, or 20 per cent.

It is interesting to record that about a dozen years ago Mr. F. Howles, who was then carrying out work in conjunction with the late Mr. Arthur McDougall, published results obtained by enriching the air with oxygen. The production from air was 34 grams of nitric acid per k.w. hour, but double that amount was given by using a mixture of 1 part nitrogen to 2 parts oxygen.

The ideal condition would be obtained by linking up the nitric acid factory with an industrial process which gives off oxygen as a by-product. There are several such industries. For example, the manufacture of hydrogen for aircraft; the manufacture of calcium cyanamide; one method of manufacturing sodium cyanide. There is also the manufacture of hydrogen for increasing the density of oils for margarine, etc.

The production of hydrogen is carried on at the aircraft factory at South Farnborough and some of the oxygen there produced is sent to Woolwich Arsenal and other works for oxy-acetylene welding but this only absorbs a portion of the output.

The oxygen produced in a calcium cyanamide factory is a by-product from the manufacture of nitrogen by the liquid air process, the nitrogen being necessary to convert calcium carbide to cyanamide. At the present time all the oxygen produced at the Odda works in Norway is wasted, because the company is not allowed to bottle and sell it. There are seven Linde plants each producing 350 cubic metres of pure nitrogen per hour, or a total of



Electric Furnace Plant.

2450 cubic metres. The amount of oxygen wasted per hour is therefore $\frac{2450 \times 21}{79} = 650$ cubic metres per hour.

This oxygen is pure; because for making cyanamide it is essential to have the nitrogen absolutely pure. Consequently it is very expensive. In the direct furnace process the case is quite different, because the oxygen is only required to raise the percentage of oxygen until it and the nitrogen are about equal. A plant to do this is simple and cheap.

Absorption System.

When the air plus the make-up oxygen passes through the furnace some of it is converted into nitric oxide and we will now trace the progress of the gases as they may be called through the rest of the apparatus.

They first go to a nest of cooling tubes made of aluminium (see top of Fig. 9), over which water is flowing, then through the preheater where some of the heat is imparted to the supply to the furnace, and then to a circular tower made of steel plates lined with acid-proof brick. This is a very large tower, and during the several minutes that it takes in passing through oxidation to nitrogen peroxide proceeds.

It then comes under the influence of the exhauster and passes into the first of the four acid absorption towers (see middle of Fig. 9). Each of these has an acid-proof open-work filling, to allow the gases and the liquor to pass freely through but at the same time bring them into intimate contact.

The gases travel up Tower 1, down Tower 2, up Tower 3, and down Tower 4. Pure water is supplied at top of Tower 4, and passing down forms, with the nitrogen peroxide, nitrous and nitric acids. The nitrous acid being unstable in an aqueous solution forms into more nitric acid and nitric oxide, and this nitric oxide changes again to nitrogen peroxide, and so on.

The final result is that dilute nitric acid runs out at the bottom, and when it reaches about 5% strength at bottom of Tower 4 it is transferred to the top of Tower 3, where it meets with stronger gas. It is then transferred to top of Tower 2, and so on, on the contra flow principle, gaining strength at each tower until it reaches any desired strength up to about 50%.

After passing the acid absorption towers some gas (up to 20%) still remains, and this can be absorbed either by sodium carbonate or milk of lime to form a solution of nitrate and nitrite, or by caustic soda to form sodium nitrite. Sodium nitrite can be made by fusing metallic lead with sodium nitrate, but the electrical way is much better and cheaper.

In proof of this, it is necessary to refer to the Badische Anilin und Soda Fabrik Works at Christiansand, in Norway, which produces all the sodium nitrite required by the company by electric furnace for direct fixation of nitrogen from air. Previously to the establishment of these works they had supplied all their requirements by the chemical method.

One remarkable feature of the products made by the direct electrical process is their extreme purity. Sodium nitrate made in Norway can compete with the natural Chilean product because of its greater purity.

The movement of the gases through the system is usually effected by fans made of aluminium, and besides those in the pipe line there may be fans to each tower.

Silicon iron or tantiron fans can be used instead of aluminium, and although more expensive in first cost they are a stronger job. Pumps of this metal can also be used for raising the acid from the bottom to the top of the towers.

It may be of interest to mention that the Tantiron Foundry at New Cross has supplied a great deal of acid resisting plant to the electro-chemical factories in Norway. This metal has come to the front very opportunely.

Although it has not been done, the writer sees no reason why the whole operation should not be carried out in a closed cycle. Several chemical operations are carried on in closed cycles, and it is a little curious that this has not hitherto been applied to the nitric acid process.

It will be seen from Fig. 9 that after passing through all the absorption system the gas and air is not allowed to escape into the atmosphere but is brought back to the furnace.

If it were allowed to escape there would of course be great waste of oxygen, but by working in a closed cycle only make-up oxygen is required, and therefore a small oxygen plant will do.

The gain is not merely in the amount of gas fixed, but there is also a considerable advantage in expediting oxidation to nitrogen peroxide.

The several absorption towers, piping, fans, etc., allow leakage, but this will not matter, for the oxygen plant merely keeps the percentage at about 50%, and to provide a little more or less oxygen is immaterial.

Products.

In order to concentrate the dilute acid from the absorption tower it is first heated to drive off some of the water, and this brings it to about 66% strength. Beyond that point more of the water can be removed by sulphuric acid.

This process is purely chemical, and the principles are well known, but of recent years a number of improvements in detail have been made to expedite and cheapen the process. That due to H. Pauling seems to be very effective.

Superheated steam as a heat carrier flows as a counter-current against a stream of nitric acid and sulphuric acid. The steam is gradually absorbed by the sulphuric acid and converted into water, whereby its latent heat is liberated for evaporation of the nitric acid. By using a path of sufficient length, nitric acid of 96% strength is obtained from a mixture containing one part of 48% nitric acid to two parts of 94% sulphuric acid.

Fig. 10 shows a typical lay out of a factory to produce concentrated nitric acid and for the details of concentration plant, and I am indebted to Mr. Glyn W. A. Foster, B.Sc., who was research chemist to H. Pauling's company, the Salterpetrasäure Industrie Gesellschaft, for many years, and who for several months carried out tests on my furnace.

For a good many industrial operations the acid can be used at about 66%, and if manufactured near to where it is to be used, there is no advantage in concentrating from the point of view of cheapening transport. For the manufacture of ammonium nitrate, fertilisers, etc., a strength of 40% or even lower is sufficient.

The manufacture of ammonium nitrate is very simple, as the dilute nitric acid direct from the absorption tower has merely to be treated with ammonia. As we have any amount of ammonia in this country it is obviously an easy and profitable product to make here.

It does not appear to be generally known that the explosives manufacturers in this country for several years have been obtaining supplies of ammonium nitrate from Norway. It has been made at Notodden by merely combining the electrically produced nitric acid with ammonia sent from this country; and as about 75% of the liquor is water, it has meant the carriage of much water and some ammonia to Norway, and finally the carriage of the nitrate back again, a good deal of it going to Nobel's works in Ayrshire.

As may be easily supposed, this business has been very profitable to a few middle-men in this country, whilst money has been going abroad which should have built up a profitable industry here.

It is this kind of thing that has caused scientific and engineering circles in Germany to get the impression of us which they have. One cannot imagine any German shipping thousands of tons of water across the North Sea for the little ammonia it contained, and then buying the product back again at a greatly enhanced price.

Owing to the war the Notodden factory is now about to obtain a supply of ammonia by treating calcium cyanamide with steam.

It was indirectly through this importation of ammonium nitrate that I took up the development of a new furnace. Some years ago I was engaged in lecturing to farmers and others regarding the new fertilisers made by electricity from air. Thinking that the time was ripe for the establishment of a factory in this country, I asked for the terms of a license

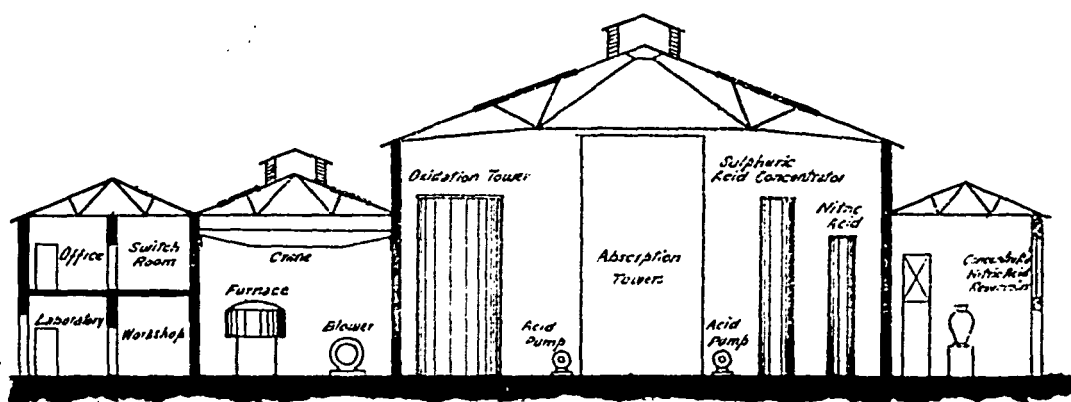
to use the Norwegian furnaces here. It was made very apparent that they did not want the manufacture started here so I decided to develop a furnace.

Later on it may be worth while to make a nitrated phosphatic fertiliser from the waste basic calcareous slag produced by open hearth steel furnaces. The slag from these furnaces is often in an insoluble or tribasic form, and so cannot be advantageously used for agricultural purposes. By treating it with dilute nitric acid or the gases from the electric furnace, a part of the phosphoric acid can be changed into the soluble form, whilst at the same time, lime in the slag is converted into calcium nitrate. The present output by this form of slag in Middlesbrough alone is about 150,000 tons per annum.

a long time. As a matter of fact at the Norwegian factories, the engineers carry on a never-ending series of tests and they are constantly trying modifications.

Samples of the gas are drawn off at regular intervals into large gas bottles which have had the air exhausted from them by a powerful pump. These are temporarily connected with the gas current by opening a tap and a sample of nitric oxide drawn in. This is changed to nitric acid and tested. Then, knowing the percentage contained in the sample, the air flowing through the furnace and the electric energy supplied, the yield can be calculated.

The effect of varying the velocity of the air passing through the furnace is very marked; it is, in fact, one



Elevation

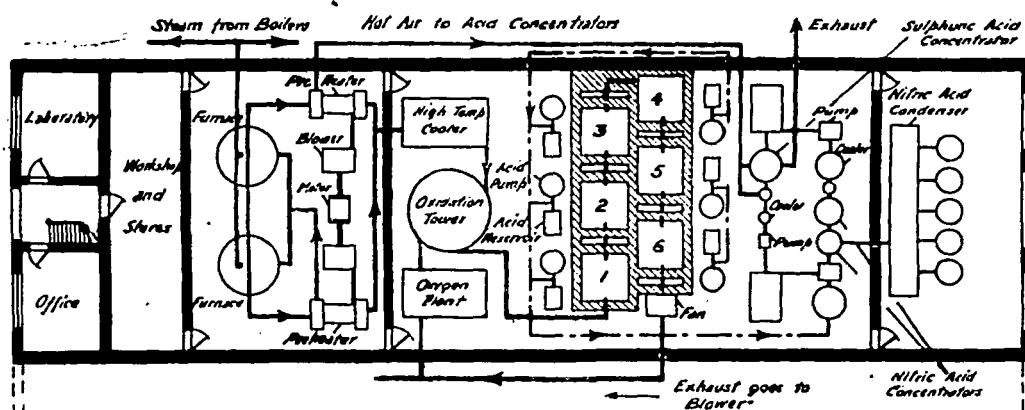


FIG. 10.

Layout of Plant for the direct manufacture of concentrated nitric acid from air by electric power.

Concentration and Yield.

To obtain the best results from a furnace a nice adjustment of conditions is necessary, for there are several factors which influence each other. For example:—

(a) The voltage and current on which depends the heat of the arc flames. (b) The pressure and quantity of air and its velocity through the arc flame. (c) The amount of preheat of the air. (d) The effectiveness of the cooling of the fixed gas. Also a number of smaller factors such as leakage, evenness of air pressure, condition of the electrodes and the furnace lining.

It will be easily seen that with so many variables the adjustment of any furnace for the best conditions takes

of the most important factors in determining on the one hand the percentage concentration of gas and on the other the yield for k.w. hour. A low velocity is favourable to a high percentage concentration, whilst a high velocity is favourable to a high yield per k.w. hour.

At various times extraordinary high percentage concentrations have been claimed. For example: Haber and König state they obtained concentrations of 9.5 to 10% with air at 100 mm. pressure. Brode is also said to have obtained 7.2% with platinum electrodes and 5.8% with iridium electrodes, and he ascribes the lower result to a decomposing influence of the fine particles of the iridium on the nitric oxide in the flame.

On the other hand, Prof. Nernst has given the following percentages as the theoretical maxima for various temperatures:—

Absolute temperature ° C.	Nitric oxide formed %.
1500	0.1
1928	0.5
2262	1.0
2403	1.5
2571	2.0
2854	3.0
3103	4.0
3327	5.0

An interesting point to note about these figures is that as the temperature rises the yield increases at a greater rate. Thus a difference of 369° C. raises the theoretical yield from 1 to 2%, whereas only 224° C. is required to raise the theoretical yield from 4 to 5%.

Since the Notodden factory was first started the percentage concentration of nitric oxide has been doubled, merely by making small modifications in furnace construction and adjusting the air supply and the electric current. Yet the percentage is still under 2%. The fact that it is so much lower than the theoretically possible is really a most promising feature of the direct method, because it indicates the great scope there is for improvement. A process that is highly efficient from the start is a very tame proposition.

High concentration is chiefly beneficial in making the auxiliary plant, absorption towers, etc., more efficient, and as these cost much more than the furnaces it is desirable.

The main thing of course is the yield per k.w. hour or k.w. year. It will be of interest to detail a few of the statements that have been published.

It is convenient to state the yield of a furnace as so many kilogrammes of pure nitric acid per k.w. year. It does not mean that pure acid is necessarily made but that the nitric oxide gas coming away from the furnace would if desired produce that amount of pure acid.

Prof. Hofer has calculated the maximum theoretical yield of pure nitric acid per k.w. year as 1850 kgs. with arc flames at 4200° C. and 819 kgs. with arc flames at 3200° C. That is to say, a difference of 225% in the yield for an increase in temperature of only 30%. These are, of course, the yields under laboratory conditions and do not include any auxiliary power, but they serve to show the very great importance of a high temperature.

In actual practice the term electric energy should really include all that is used for working the furnace and not merely the energy of the alternating current arc. For example, it should include the losses in the choking coils and resistances, and in the case of the Birkeland-Eyde furnace the energy taken by the magnetising coils. It should also include the motive power for driving the blowers, etc., because some furnaces require more power to blow the air through them than others. Continuity of working is also most important.

Pauling guarantees 60 grammes of nitric acid per k.w. hour of electric energy measured at the factory switch-board, and this is equal to:—

$$\frac{60 \times 8760}{1000} = 525 \text{ kg. k.w. year,}$$

For 8000 hours a year this gives 480 kg. or just under half a ton per annum.

Dr. Eyde has stated that at the Notodden factory the output per k.w. year is 853 to 938 kgs. of nitrate of lime containing 13% of nitrogen, or reckoned in pure nitric acid, it averages 500 to 550 kgs. with 900 kgs. as the best result.

In another statement the annual production at Notodden is given as 20,000 tons of nitrate of lime, 4000 tons of sodium nitrate and 4000 tons ammonium nitrate. As the Notodden factory is supplied with electric energy from a power house containing four turbo alternators each of 10,000 h.p. or 30,000 k.w. in all, this works out at 0.66 ton of nitrate of lime, 0.133 ton sodium nitrate and 0.133 ton of ammonium nitrate per k.w. year.

The estimate of the annual production of the Saaheim factory has been given as 70,000 tons of nitrate of lime and 8000 tons of sodium nitrite. The Rjukan power house has ten turbine generators aggregating 100,000 k.w.,

so this works out at 0.7 ton of nitrate of lime and 0.08 ton of sodium nitrite per k.w. year.

Averaging up all the above it is safe to assume that a nitrogen fixation plant with single-phase furnaces on existing lines will give the equivalent of half a ton of pure nitric acid 96% per k.w. year, or stated in the other products which are manufactured, say three-quarters of a ton of nitrate of lime, and one-tenth of a ton of sodium nitrate.

Conclusion.

I am convinced that it is possible to considerably increase the present yields, and to summarise briefly the following are some of the reasons:—

Gain by regenerative working.—Theoretically the energy saved by using steam from the boiler to generate electricity is about 15%.

Gain by oxygenated air.—By blowing through the furnace equal parts of oxygen and nitrogen instead of air the yield is increased by 20%.

Gain by increased temperature.—The theoretical yield increases from 819 to 1850 kg. per k.w. year or 225%, when the temperature of the arc flames is increased from 3200° C. to 4200° C. or only 30%.

I claim that a combined three-phase arc flame is hotter and acts on more of the air than three single-phase flames each in separate furnaces, and that, taken in conjunction with the other features of my design detailed above, including the effective cooling, by a boiler, using the steam so raised regeneratively, and also blowing oxygenated air through the furnace, a yield considerably in excess of that obtained in Norway is possible.

When considering manufacture, one naturally thinks first of water power. It is true that such powers as we have are not large; but the assumption that they are not worth harnessing, or if developed electrical products cannot be made profitable, is quite untrue. The success of the aluminium works in Scotland and North Wales is evidence of that.

As a matter of fact, it should not cost any more, if as much, to harness a water power here as it does to harness a similar one abroad, because the main expense is in the hydraulic and navvying work, the concrete dams, and steel piping, etc. Unfortunately, we are handicapped by difficulties in obtaining necessary authority from Parliament. No doubt in the future nitrates will be made by electric energy from a water power, but it is not necessary to wait for that.

Our main concern is to make nitrates now, and the obvious thing to do is to take the energy of an existing power station, preferably one utilising waste heat. Such stations have a great advantage over water power in being situated in industrial centres where carriage of raw materials and finished products is small.

For solutions such as nitric acid and ammonia the question of carriage is all important, and it is one reason why so many factories have their own plants to make acid from sodium nitrate. The lowest price, however, at which it can be made in that way in normal times is about £18 a ton, reckoned as pure concentrated acid. The electrical method can produce it much cheaper. Working on a restricted hour basis is no disadvantage, because nitrogen fixation furnaces can be switched on and off at any time like arc lamps. They thus make an ideal load for "off-peak" hours.

Although the cost of electricity is higher than in Norway this is not a very material factor, because the carriage of ammonia to Norway and ammonium nitrate back, and especially the carriage of nitric acid over the sea, is several times greater per ton than the cost of power per ton to manufacture the product.

The carriage of such solutions across the sea and on the railway is difficult, for it is not merely a question of finding ships to accept such cargo at reasonable rates, but special heavy tanks have to be provided and to be maintained. As a matter of fact, the carriage of nitric acid from Norway has not been attempted.

Even if Norway could compete, the establishment of factories in this country to make nitric acid, ammonium

nitrate, and sodium nitrite from the air is a national duty. They are urgently wanted for explosives and for the aniline dye industry.

Now that a Special Committee has been appointed to assist in the establishment of chemical industries hitherto carried on abroad, I hope it will not be long before we have factories for producing nitrates from the air by electric power.

DISCUSSION.

The author was asked what would be the smallest practicable commercial unit. One of the main advantages of Pauling's furnace was, that it could make small quantities of acid, such as were used in many manufacturing processes, and at a reasonable cost.

Mr. KILBURN SCOTT said he would naturally prefer to work continuously and on a large scale, but the direct electric process could be economically worked on a moderate scale and also intermittently. His idea of a small commercial unit would be about 1000 kilowatts, having say three furnaces of 330 kilowatts each. A thousand-kilowatt plant, including furnaces, absorption towers, circulating fans, piping, and all auxiliary apparatus, but not including the steam turbine which he proposed should be a part of the system when working regeneratively, could be put down for something like £6 or £7 a kilowatt. Of course, the larger the plant the lower the cost per kilowatt: thus for a 10,000-kilowatt plant the price per kilowatt would come down to £5 or £6 per kilowatt. This price per kilowatt was a convenient way to state the cost of the installation, but it must be understood that the bulk of the £5 or £6 was not for furnaces and electrical gear but for the absorption towers, circulating fans, piping, and other non-electrical apparatus. The purely chemical part of the plant was the most expensive and occupied most space. It would be feasible to start with a smaller plant than one of 1,000 kilowatts; for example, one might have first a 330-kilowatt furnace, then add another 330, and so on, or the units might be two of 500 kilowatts each. He did not think it would be commercially advisable to go smaller, but it all depended on local conditions and the cost of energy and of carriage.

Mr. G. NEVILL HUNTLY said that some seven or eight years ago he tested a nitric acid plant by Moscicki. The main point claimed by the inventor was not that the yield of nitric acid per kilowatt-year was notably increased, but that the concentration of nitric oxide was greater. He thought that at that time the concentration at the Notodden works in Norway was about 0.75%. The Moscicki furnace was said to give about 2%, and the inventor claimed for that a considerable saving in the capital cost of the absorbing system. As the Moscicki furnace had not been mentioned by Mr. Kilburn Scott, he assumed it had not been commercially successful, although the inventor was one of the pioneers in the preparation of nitrates from the air.

Mr. KILBURN SCOTT said that all the furnaces in use abroad worked with a single-phase arc, and whether the arc flame was produced one way or the other, as a long-standing arc blown by a whirling current of air, or magnetically directed as in the Birkeland-Eyde and Moscicki furnaces, the temperature and electrical conditions were pretty much the same. Also, as the cooling was effected by excess air in all these single-phase furnaces the possible concentrations would not vary much; they all appeared to give $1\frac{1}{2}$ to 2%, depending on the velocity of the air. All single-phase furnaces at present in use had certain inherent defects, and the concentration and yield was limited thereby. His own furnace had a 2-phase arc flame which was hotter and of better

shape to ensure contact with the air than single-phase flames, each in a separate furnace. The radiation losses of the 3-phase furnace were much lower, and it had many other advantages which he had pointed out. The hotter flame gave better results, and the efficient cooling by the boiler also gave more fixed gas, whilst at the same time generation of power by steam from the boiler would materially reduce the total power drawn from the main supply. These improved conditions would give both a higher concentration and a higher yield, both of the two he considered the yield was the most important.

The author was asked if the presence of moisture in the air and the introduction of steam influenced the equilibrium. Also, did air pressure influence the yield?

Mr. KILBURN SCOTT said that Professor Guye had stated the yield was increased somewhat if the air was freed from moisture. If there should be a water leak from the electrodes the yield would drop immediately. As to the use of high pressure opinions differed widely. In 1907 Briner and Durand obtained higher percentages by lowering the pressure. Schönher claimed that the vertical movement of the ascending current of air lowered the pressure in the centre of the air column, and that tended towards higher yields. On the other hand, Muthmann and Hofer in 1903 noted that while using the higher temperatures of the electric arc a marked increase in yield accompanied the use of compressed air. Rossi, in some experiments with air up to 50 atmospheres, is said to have succeeded in converting one-third of the oxygen present into nitric oxide and securing concentrations of 10% NO. Haber experimented in 1910 with a small Schönher furnace with pressures up to 20 atmos., and was led to the conclusion that an increase of pressure offered no practical advantage. Personally he (the author) thought there would be a number of mechanical difficulties in getting high pressures inside commercial furnaces constructed of refractory bricks for all such linings were porous. In the construction of electric furnaces a number of electrical details had to be carefully considered. For instance, when dealing with alternating electric currents inside a steel structure, it was necessary to avoid "eddy currents," i.e., currents induced in the steel structure. The efficient insulation of the electrodes where they passed through the wall of the furnace was also important. Great pressures could be attained in laboratory apparatus which were quite out of the question on a commercial scale. No doubt an electric furnace for fixation of nitrogen could be made tight against high pressures, but it was not clear that there would be sufficient advantage to make it worth while. The direct process gave good results without high pressure. Regarding depreciation he did not think it would be more than 10%. The lining of his furnace was remote from the arc flames, being behind the electrodes, and it was a very simple firebrick structure. The depreciation of the boiler would be higher than that of the furnace proper, but on the other hand depreciation on the absorption towers was very low. They were built on the lines of a brick chimney, and it was usual to allow only 2% for depreciation there. As the absorption plant formed the largest and most expensive part of the plant, 10% depreciation on the cost of the whole system was ample. There was no expensive catalyst or other expensive material to renew. There was nothing to go wrong with the furnace; it was more robust than an arc or induction furnace for smelting metals. He agreed with Mr. Lynn that by-product recovery was the proper way to generate power from coal, and that if produced in that way it could be sold in bulk for a 24-hour supply at a price that would compare

favourably with Norwegian water power. It would of course be more profitable to run the plant 8760 hours per year, as against the restricted hour basis of 5200 hours a year. At the same time these furnaces could be switched on and off at any time. Under such conditions a certain amount of heat energy would be lost by radiation during the periods of stopping and starting. That might be got over by passing a certain amount of current through a heating rheostat at a low voltage so as to keep the lining, etc., warm during the standing hours.

Mr. A. H. LYNN said that the capital cost of nitric acid plant in Norway had been very high indeed. It would be interesting to know what was Mr. Kilburn Scott's idea as to cost of a plant for direct fixation of nitrogen. The author had omitted to mention the production of power by making producer gas and simultaneously recovering by-products. If such a plant were erected near collieries where suitable coal was obtainable, the gas could be obtained for nothing, or even at a profit. By utilising this gas either in large gas engines or under steam boilers and utilising steam turbines, power costs of 0.1 penny per kilowatt-hour could be attained in Great Britain, not on the restricted service basis of 5200 hours a year, but continuously for 8760 hours per annum. He (the speaker) had installed such plants for the *Badische Anilin und Soda Fabrik*, and also for the *Hoechst Farbwerke*, for electro-chemical purposes, to use even comparatively expensive coal. It was probable that the electric furnace could be utilised much more profitably if it could be worked continuously.

Mr. W. F. REID said that perhaps Mr. Kilburn Scott had not had the opportunity of trying his boiler on a large scale; others had found it was not practicable to expose a boiler to such a great heat. The heating of the water might possibly be managed, but the nitrous gases corroded the metal very rapidly. The great difficulty was to cool the gases as soon as possible after the initial fixation of the nitrogen, because otherwise the nitrogen compounds produced were decomposed again by the heat. In the Pauling process the gases were cooled in a very ingenious way by means of an English invention. The stoves designed by Cowper to heat the air supply for blast furnaces were used, but the process was reversed. There were two of them in the plant shown in one of the figures. The hot gases and air passed through the chilled brickwork, and the brickwork took up the surplus heat. The two chambers were used alternately, so that the gases could be chilled without great wear and tear. He had not the slightest doubt, in view of the experience already gained on the matter, that 10% depreciation of a boiler in that position would not be nearly enough. The absorption of the gas seemed to him to be a great problem. A small quantity of a valuable product had to be absorbed when mixed with a very large quantity of gas. He had visited several of the factories, and at most of them large volumes of orange fumes were escaping at the exit. The bulk of the nitric acid used in this country must be concentrated; dilute acid was of very little use. In some of the factories an ordinary tower was used like those used to concentrate waste acid in explosives factories, which worked fairly satisfactorily. He was inclined to think that the future of the industry would lie in the oxidation of ammonia made from the atmosphere. Large quantities of nitric acid were being made in Belgium by that process, until the Germans interrupted it. There was no necessity to take the ammonia from this country to Norway in order to get nitrate of ammonia when they had the means of producing it from the atmosphere. In the direct electric process a small quantity only of the electric power was utilised in producing combination of the two gases. If the waste heat could be

economised, and power produced in some better way than Mr. Kilburn Scott suggested doing with his boiler, a great proportion of the power might be economised. So far he was not aware of any process that did that, but it would give enormous economy. It would be a more efficient process if the only energy lost was that employed in the actual combination. Mr. Kilburn Scott placed the minimum power required for a factory very low indeed when he said 1000 H.P. If anybody had surplus power they might utilise a portion to make nitric acid. Personally he would not advise the erection of plant under 40,000 or 50,000 H.P. He quite agreed with what had been said with regard to producer gas power. With the utilisation of waste products on the spot where the stuff was wanted and used, he thought they could compete with a factory which had in the first instance to put up plant to utilise water power. The cost of harnessing water power was very considerable, and they usually had to carry the material a very great distance, and the carriage of such materials at the present time was a serious matter. He had sought out all the water power in Scotland, but the biggest sources were taken up, and the reason the others were not utilised was because it would not pay on such a small scale.

Mr. KILBURN SCOTT said that it was not until the nitric oxide changed to nitrogen peroxide that it attacked metal, and that change did not take place until the temperature had dropped to below 400° C. Now the temperature of the arcs in these furnaces was somewhere about 3000° C., whilst the temperature at which the gases left the furnace was just under 1000° C. For example, Eyde had stated that the gases left his furnace at between 800° and 1000° C., and Schönher had given about the same figures. Now 900° C. was below the temperature at which gases entered the tubes of high-class boilers. Boilers were used in Norway for the purpose of raising steam for various industrial purposes in the factory; in fact, evaporation of the products was about the only purpose they had to use the steam for. The gas entered the boilers at about 400° C., and left at about 200° C. Therefore it was clear that the gas went into the boilers at under the temperature at which it had changed into nitrogen peroxide, and as already stated it was not until it had changed into nitrogen peroxide that it attacked metal. He thought 10% depreciation was enough.

The Cowper stoves installed at the plant in the Haute Alpes were at some distance from the furnaces, and their purpose was solely to cool the gases and not to prevent dissociation. Dissociation must be prevented in the furnace itself, and in the Pauling furnace it was effected by blowing a separate supply of cooling air into the top of the arc flames. Before the gases reached the Cowper stoves they had already passed through the preheater. The most scientific and efficient way to cool the fixed gases was to take advantage of the latent heat of steam to absorb the heat rapidly. With regard to acid concentration, it was well known that acid could be brought up to 60% by mere heat evaporation. The absorption towers would give up to 50%, but up to 30 or 40% strength would do to make such products as calcium nitrate and ammonium nitrate. The Ostwald catalytic process in use in Belgium, at Vilvorde, made the acid at 40 to 50%, so that for the higher concentrations the sulphuric acid plant was required for that just as for any other process. As regards the minimum horse-power advisable for the plant, one nitric acid factory complete with Cowper stoves worked by power from a glacial stream, etc., absorbed only 4000 kw., having nine furnaces of 450 kw. each. Another plant which had been running most successfully in Italy for many years with energy purchased from a power company took 7500 kw. Ten years

ago the largest plant in Norway was of only 120 kw. capacity. A nitric acid factory at Legnano, near Milan, which had been using Pauling furnaces for many years worked on that restricted service. It used 7500 kilowatts, and electric energy was supplied by a power company during the off-peak hours at 20s. per kilowatt-year.

One considerable source of waste power which could be readily harnessed for the electric production of nitric acid was that of modern by-product coke oven plants, which gave a surplus of about 50% of the whole gas produced. Mr. Twynam, of Middlesboro, and himself were interested in a proposal to convert this waste gas into electrical energy, then utilise the energy in a Kilburn-Scott furnace for the production of nitric acid, and finally combine the nitric acid with the ammonia in the whole of the coke oven gases so as to form nitrate of ammonia. Figures which had been got out showed that it would be more profitable to use the surplus gas and the ammonia in that way than merely to make the less valuable sulphate of ammonia, as at present, the sulphuric acid for which had to be purchased.

The Ostwald patents for making nitric acid by the catalytic process taken out about a dozen years ago, were transferred in April, 1910, to a company called Nitrates, Ltd., promoted by Mr. A. S. Barton. Not only had there been no profits, but Mr. Barton had admitted that the process had been most inefficient, and £78,604 had been spent in twelve months on account of the factory.

Meeting held at Burlington House on Monday, February 1st, 1915.

MR. W. F. REID IN THE CHAIR.

Specimens of chemicals and apparatus were displayed, which hitherto have been mainly produced abroad, but now are being manufactured in this country.

The following is a list of the exhibitors and products:—

*Messrs. Baird and Tatlock, Ltd. (London).—*Glass apparatus of their own manufacture, porcelain boats and crucibles, thermometers, burettes, and reagent chemicals.

*Messrs. W. and R. Dalston, Ltd. (Maidstone).—*High-grade filter papers, suitable for laboratory analysis.

*Messrs. A. Boulke, Roberts and Co., Ltd. (Stratford).—*Anethol, eugenol, citral, citronellal, geraniol, triacetin, terpeneless oils of lemon and ginger.

*The British Glass Wool Co. (2, Compton Road, N.).—*Glass wool.

*The British Laboratory Ware Association, Ltd.—*English-made glass beakers, flasks, tubing, etc., Doulton porcelain ware, and Royal Worcester porcelain crucibles, etc.

*Messrs. Butterworth Bros., Ltd. (Newton Heath, Manchester).—*Glass tubing, Tenax leadless resistance glass, canes for tungsten wire.

*Corlicine Floor Covering Co., Ltd. (Aldersgate Street, E.C.).—*Articles of compressed cork.

*Messrs. Higgins Bros. (Liverpool).—*Salicylic acid.

*Messrs. Johnson and Matthey (Hallon Garden, E.C.).—*Magnesium metal and powder, barium platinoeyanide for X-ray screens.

*Manchester Oxide Co. (Manchester).—*Pure barium and ammonium sulphocyanides.

*Morgan Crucible Co., Ltd. (Battersea, S.W.).—*Combustion and pyrometer tubes.

*Messrs. James Powell and Sons (Whitefriars Glass Works, E.C.).—*Glass flasks and tubing.

*Messrs. A. G. Thornton, Ltd. (Manchester).—*Sectional papers, true to scale, replacing German-made products.

After a brief description of the exhibits had been given, Mr. J. J. EASTICK moved a resolution urging the Government to take such steps as would tend to the production and refining within the Empire of sugar sufficient for the Empire's consumption. The resolution was supported by Capt. G. L. Courthope, M.P., Mr. C. S. Parker, Mr. W. T. Chadwin, and Mr. Buckmaster. Further discussion was adjourned till March 1st, 1915.

Manchester Section.

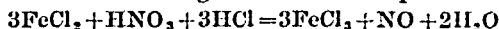
Meeting held at the Grand Hotel, on Friday, December 4th, 1914.

MR. JULIUS HÜBNER IN THE CHAIR.

A RAPID METHOD OF ESTIMATING NITRATES.

BY EDMUND KNECHT.

The oldest method for the quantitative determination of combined nitric acid is that of Pelouze, in which a known weight of the substance to be assayed is boiled with excess of ferrous chloride (or sulphate) and concentrated hydrochloric acid, when the following reaction takes place:—

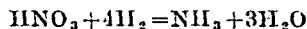


The remaining ferrous chloride is then estimated either with standard bichromate or permanganate. An alternative method (Knecht and Libbert, "New reduction methods in volumetric analysis," p. 67) is to estimate the ferric chloride directly by means of titanous chloride.

The nitrometer of Lunge affords a rapid and accurate means of estimating combined nitric acid, and is perhaps the most universally used, especially in works practice. It is based upon the fact that nitrates, in presence of concentrated sulphuric acid and metallic mercury, yield the whole of their nitrogen as nitric oxide, which is measured directly as such.

A third method is a gravimetric one and is based upon the property of diphenyl-endanilohydrotriazole (Nitron) of forming a sparingly soluble precipitate with nitrates.

A fourth method of estimating nitrates is based upon the quantitative reduction of nitric acid to ammonia in presence of excess of caustic alkali by means of a suitable reducing agent, according to the scheme:—



The ammonia formed is collected in standard sulphuric acid and the extent of the neutralisation of this is ascertained by titration with standard alkali, or in case very small quantities only are present the distillate is nesslerised. The reducing agent originally employed in this method was zinc dust, but later it was found that aluminium was more suitable for the purpose. In both cases, however, a considerable amount of time was considered necessary to effect complete reduction.

In a paper published in 1903 (Ber., 36, 166; this J., 1903, 232) the author drew attention to the fact that titanous hydroxide was capable of effecting the complete reduction of nitrates to ammonia. A further examination of this reaction showed that the reduction is almost instantaneous.